COMPARISON OF PROFILE MODIFICATION TO TRADITIONAL TILLAGE FOR COTTON PRODUCTION ON TUNICA CLAY

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ABSTRACT. *A field study was established in the fall of 1993 on Tunica clay soil to evaluate the response of cotton to profile modification tillage relative to more conventional types of tillage for clay soil. Ten treatments were replicated four times using plots 15 m wide × 30.5 m long in a wide-bed controlled-traffic production system. Annual tillage treatments included bedding, disking, chiseling, subsoiling, and profile modification to depths of 25 cm, 50 cm, and 76 cm. Treatments to evaluate the residual effects of tillage were also included for the 25 cm, 50 cm and 76 cm depths of profile modification. Results indicated that soil profile modification generally increased plant height, vegetative dry mass and seed cotton yield compared to conventional tillage practices. In the modified profile treatments, crop response increased as depth of modification increased. The residual effect of soil profile modification at the 76 cm depth was as effective in increasing seed cotton yield as annual profile modification after three years. Soil profile modification produced a positive response in cotton production but the time required to perform the tillage was excessive.*
Keywords. *Cotton, Clay soils, Soil profile, Soil structure, Tillage modification.*

Clay soils make up about 50% of the soil in the Lower Mississippi Delta. These soils are very fertile but crops grown on them quickly experience water-deficit stress during dry periods of the growing season. This condition can be alleviated by irrigation, but it is too expensive for most farmers to use. The clay soils are usually reserved for crops with relatively low profit potential; therefore, it is difficult to justify the high investment required for irrigation. Prior work (Wesley and Smith, 1991; Smith, 1995) has shown that deep tillage in the fall, in relatively dry clay, provides an alternate solution to the water-deficit stress problem. This solution is thought to be the result of rearranging the structural soil units (blocks) so that the volume of macro-pore space between them is increased. Therefore, water infiltrates into the soil at a faster rate, increasing free water storage, and surface runoff is reduced. This investigation extends the concept of increasing macro-pore space volume from rearranging soil structural blocks to breaking up the structural blocks by the process of profile modification.

Modification of the soil profile has been used to promote better soil water relations and alleviate mechanical and chemical restrictions to root growth. Mech et al. (1967) used a backhoe to modify the profile of a silt loam topsoil overlaying a clay subsoil. By mixing the A and B soil horizons, they decreased soil bulk density, increased root proliferation in the B horizon, and generally increased crop yields. Eck and Taylor (1969) used a trenching machine to modify the profile of a Pullman silty clay loam. Profile modification to depths of 91 cm and 152 cm improved grain sorghum yields by 66 and 80%, respectively, compared to non-modified plots. Heilman and Gonzalez (1973) modified a Harlingen clay soil with a trenching machine by using trenches 12.5-cm wide spaced 102 cm apart. This treatment, installed to a 61-cm depth, improved cotton yields by 22% with soil backfill and 43% with soil-vermiculite backfill. Cotton yield improvement with soil backfill for a 102 cm modification depth was 25% compared to non-modified treatments.

The study of profile modification effects on crop production has been limited due to the absence of an implement specifically designed to perform the modification. Profile modification has been performed with a variety of machines ranging from backhoes to trenching machines that were not designed for the modification task. A machine was needed which would efficiently break up the soil structure and leave the soil in a condition compatible with crop production without the use of heavy earth moving equipment. Such a machine was designed, constructed, and tested (Smith, 1993) in a wide-bed controlled-traffic production system (Williford, 1980) on Tunica clay.

PROCEDURE

A field experiment was established during the fall of 1993 on Tunica clay (clayey over loamy, montmorillonitic, non-acid, thermic *Vertic Haplaquept*). Ten treatments, replicated four times, were installed in plots 15 m wide (6 wide-beds) × 30.5 m long using a wide-bed controlled-traffic production system (table 1). Two rows of cotton spaced 1m apart were planted on each wide-bed (fig. 1).

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Table 1. Tillage treatments and implements used to install them

Treat-ment	Description	Implement
1.	Bed-only	6-row hipper
2.	Disk harrow and bed	Disk harrow (twice); 6-row hipper
3.	Chisel 20-25 cm deep and bed	2-m wide chisel plow; 6-row hipper
4.	Subsoil 40-45 cm deep and bed	Parabolic subsoiler (2 shank @ 1-m spacing); 6-row hipper
5.	Profile modification (76 cm deep, annually)	Experimental modification implement (1.4 m wide × 0.76 m deep); rice levy plow to shape
6.	Profile modification (50 cm deep, annually)	Same as 5 but (1.4 m wide × 0.50 m deep)
7.	Profile modification (25 cm deep, annually)	Same as 5 but (1.4 m wide × 0.25 m deep)
8.	Profile modification (76 cm deep, residual)	Same as 5 first year, but disk and hip thereafter
9.	Profile modification (50 cm deep, residual)	Same as 6 first year, but disk and hip thereafter
10.	Profile modification (25 cm deep, residual)	Same as 7 first year, but disk and hip thereafter

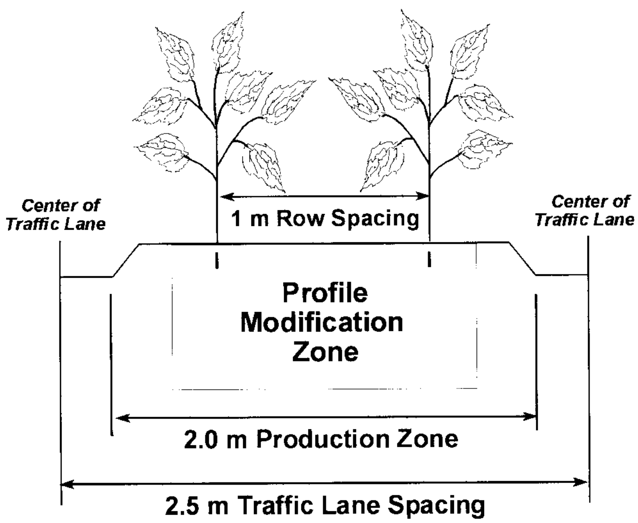

Figure 1–Wide-bed controlled-traffic production system which restricts machinery traffic to the 0.5-m traffic lane. The profile modification zone (1.4 m wide) was centered on the production zone and varied in depth from 25 to 75 cm depending on the tillage treatment.

Figure 2–Profile modification machine operates from tractor supplied PTO power and controls forward travel while modifying the soil profile. During transport and turning phases of operation, the propelling mechanism is disengaged and the implement trails the tractor.

Profile modification treatments (T5 through T10, table 1) were installed with an experimental implement designed to perform the equivalent of a trench-backfill operation in a single pass (fig. 2). It was operated from the tractor PTO and used a creeping drive mechanism on the implement to control forward travel speed of the machine. While digging, the implement pushed the tractor (tractor transmission in neutral), but while transporting or turning, the drive mechanism of the implement was disabled hydraulically to allow it to operate as a trailed implement. This implement modified a strip 1.4 m wide to a maximum depth of 76 cm. The depth could be set to any desired value between 0 and 76 cm by using auxiliary tractor hydraulics. Power requirements for most clay soil conditions were less than 45 kW. Forward travel ranged from 0.047 to 0.071 km/h with most soil conditions, but speeds of 0.10 km/h could be achieved with shallow depths on light textured soils.

The field experiment was continued for crop seasons 1994, 1995, and 1996, but early rains after harvest of the 1994 crop prevented the profile modification required by treatments 5 through 7. The 1995 crop was further complicated by the lack of a consistent stand; therefore, the 1995 data will not be included in this report. Table 2 summarizes the significant practices used in the field experiment. The primary tillage was completed each year during the fall. The modification process resulted in a mound of loose soil across the modified strip which was sometimes almost 60 cm in height depending upon the soil conditions and depth of modification. Some of this soil spilled out on to the traffic lane and had to removed with a rice levee plow that mounded the loosened soil across the production zone. The mounding operation insured that the production zone would settle to a level above the traffic lanes as it weathered during the winter. All treatments were lightly smoothed in early spring with a spring-toothed harrow and allowed to settle before conditioning the seedbeds and planting. Modified profile treatments required one extra smoothing with the harrow to flatten the soil across the production zone.

Winter vegetation was killed before planting time with one application of Glyphosate. In 1994, soil tests revealed

Table 2. General crop production practices

Practice	1994	1996
Fall tillage	10/07/93	11/27/95
PM* bed-shaping	3/22/94	3/4/96
Planted	4/26/94	5/7/96
Supplemental fertilizer†	67 kg/ha (0-20-20)	None
Initial nitrogen	104 kg/ha	110 kg/ha
Side dress nitrogen	22 kg/ha (6/11/94)	28 kg/ha (7/1/96)
Irrigation	None	None
Harvest	9/28/94 - 10/4/94	10/9/96

* Profile modification treatments.

† Based on results of soil test; applied to modified profile treatments only.

that the modification process had brought subsoil to the surface that was low in potash and phosphate. Therefore, supplemental fertilizer (0-20-20) was applied at a rate of 67 kg/ha to the modified treatments only. At planting time, a seed bed conditioner was used to freshen the seedbed just prior to planting. Stoneville 453 cotton variety was planted each year. Cotoran 4L (3.7 L/ha) was tank mixed with Dual 8E (2.3 L/ha) as a pre-emergence weed control measure. In 1994, in-furrow insecticide and fungicide (Temik 15G and Ridomil PC 11G) were applied due to the early planting date. Initial nitrogen was applied as NSOL and knifed into the seedbed about 15 cm from each side of the seed furrow (table 2). Side-dress nitrogen was applied as ammonia nitrate and was broadcast uniformly across the production zone with a three-point hitch mounted Gandy distributor. Recommendations from a professional cotton scout were followed for controlling insect pests throughout the growing season and insecticide treatments were uniformly applied across treatments. Dry mass measurements during the growing season were made by grinding plant samples in a hammer mill and then drying the crushed sample in a convection drying oven at 70°C until moisture change over a 24-h period was 1 g or less. The crop was produced without supplemental water and harvest was performed in late September and early October (table 2). In 1994, seed cotton samples were collected at the first harvest and ginned on a micro-gin at the USDA-ARS Ginning Laboratory, Stoneville, Mississippi. The ginned lint was then sampled and submitted to the Cotton Classing office at Dumas, Arkansas, for the measurement of fiber quality.

RESULTS AND DISCUSSION

Data were collected during the 1994 season to document differences in the response of plant growth to the tillage treatments. Average height, specific plant dry mass, average plant dry mass and average Nodes Above White Flower (NAWF) as measured on 8/2/94 are presented in table 3. In general, plants in treatment 1 (rehip old beds) were shorter and produced less dry mass than plants in other treatments at the time of data collection. Modified profile (PM) treatments, numbered 5 through 10, were generally taller and produced more dry mass than other treatments. Treatments 2 through 4 (disked, chiseled, and subsoiled, respectively) fell between treatment 1 and all PM treatments in height and dry mass production. It should be noted that the 1994 crop season was the first year of the study; therefore, the residual PM treatments (8, 9, and 10) were the same as annual PM treatments 5, 6, and 7, respectively. Treatment 8 had the tallest plants and greatest specific vegetative dry mass. This treatment was statistically similar ($P > 0.05$) to all other treatments except treatment 1 in height and similar to all except treatment 1 and 3 in specific vegetative dry mass. Average dry mass was greatest in treatment 7 and was statistically similar to all treatments except 1, 2, and 4. The measured value of the 'Nodes Above White Flower' (NAWF) parameter gave an indication of the stage of crop maturity. All treatments had statistically similar NAWF and this indicated that the tillage treatments did not significantly delay or advance maturity of the crop.

Yield data from 1994 and 1996 are presented in table 4. These data follow the same trend that was exhibited in the plant measurement data. Treatment 1 produced the least amount of seed cotton each year and the 50 cm and 76 cm depths of profile modification produced the greatest amount of seed cotton. In 1994, the 76 cm PM depth produced significantly more seed cotton than all non-modified treatments at the 0.05 level of probability. Yield from the 50 cm PM depth was similar to the yield from the 76 cm PM depth, but was significantly greater than treatments 1 and 4. In 1996, the 50 cm and 76 cm annual PM depths and the 76 cm residual PM depth yielded significantly greater amounts of seed cotton than treatments 1 and 4.

One surprising result from this study was the poor showing of treatment 4 relative to other non-modified treatments. Previous studies comparing subsoiling with disking showed that subsoiling was significantly better than disking as a primary tillage practice for growing cotton as well as soybean. Plentiful precipitation and problem weeds contributed to the poor response to subsoiling.

Plentiful precipitation (table 5), especially during the months of May, June, and July, was the primary factor that caused the subsoiled and disked treatments to respond in a

Table 3. Plant growth measurements from the 1994 crop season*

Treat-ment	Description	Average Height (cm)	Specific† Vegetative Dry Mass (g/m²)	Average Plant Dry Mass (g)	Average NAWF‡ (no.)
1	Rehip - annual§	77.3	269.4	39.1	3.9
2	Disk - annual	82.4	363.8	40.7	4.6
3	Chisel - annual	78.6	389.2	43.9	4.2
4	Subsoil - annual	86.3	350.8	39.6	4.5
5	76 cm PM - annual	96.0	430.5	62.7	4.2
6	50 cm PM - annual	93.5	439.1	62.8	4.4
7	25 cm PM - annual	93.3	416.1	66.0	4.9
8	76 cm PM - residual‖	97.3	483.3	65.8	4.3
9	50 cm PM - residual	93.1	459.2	58.3	4.4
10	25 cm PM - residual	92.3	397.8	53.3	5.1
	$LSD_{0.05}$	18.0	179.1	23.4	1.9

* Measurements were made on two replicate samples, each consisting of all plants growing on a row length of 1 m.
† Based on 102-cm row width.
‡ Nodes above white flower.
§ Tillage performed annually in the fall after harvest.
‖ Profile modification tillage performed fall of 1993 only.

Table 4. Seed cotton yield (kg/ha) produced by tillage treatments from the profile modification study using a wide-bed controlled-traffic production system on Tunica clay

Treat-ment	Description	1994*	1996*
1	Rehip - annual†	2318 d	2010 b
2	Disk - annual	2774 bc	2642 ab
3	Chisel - annual	2734 bc	2634 ab
4	Subsoil - annual	2635 cd	2225 b
5	76 cm PM - annual	3289 a	2966 a
6	50 cm PM - annual	3034 ab	2973 a
7	25 cm PM - annual	3029 ab	2669 ab
8	76 cm PM - residual‡	3219 a	2967 a
9	50 cm PM - residual	2889 bc	2679 ab
10	25 cm PM - residual	2653 c	2484 ab
	$LSD_{0.05}$	319	688

* Yield values followed by a common letter do not differ significantly at the 0.05 probability level.
† Tillage performed annually in the fall after harvest.
‡ Profile modification tillage performed fall of 1993 only.

Table 5. Precipitation received on the profile modification field plots as measured by a rain gage located adjacent to the field

Month	30-year Average* (cm)	1994 (cm)	1996 (cm)
May	12.6	10.6	4.9
June	9.5	6.1	14.6
July	9.3	20.8	7.9
August	5.8	1.4	5.8
September	8.6	1.4	11.8
Total	45.8	40.4	45.0

* Measured at the Stoneville, Miss., official NOAA weather station.

similar way. In 1994 and 1996, a total of 40.4 cm and 45.0 cm of precipitation was received, respectively, during the five months May through September. In 1994, only 2.8 cm of precipitation was received during August and September; however, the plentiful precipitation in July allowed the harvestable fruit already set on the plant to mature. It has been well documented that water is the primary cause of crop response to tillage on clay. Prior studies demonstrated that when sufficient water was available to prevent water deficit stress during critical times of fruiting, response to disking and subsoiling were the same (Smith, 1995; Wesley and Smith, 1991). However, during dry periods, the disked treatments experienced stress sooner and more severely than subsoiled treatments and yields were significantly reduced.

The other factor reducing the yield response to subsoiling was a buildup of problem weeds. Honeyvine milkweed (*Ampelamus albidus*), a perennial, twinning, deciduous herb which is almost impossible to control with herbicides, became a problem in several treatments but predominately in treatment 4 and treatment 1. The tillage of these treatments did not bury the weed seed or disrupt the root system sufficiently to maintain control. These treatments had been on the same plots during a prior study, installed in 1987, comparing subsoiling with disking. While the effect of this weed on yield response cannot be attributed directly to tillage, it is an indirect result of the use of these two tillage practices on a long term basis without supplemental tillage as needed to disrupt the weed root system.

The standard of comparison for the PM treatments will be the average of treatments 2 and 3 due to the weed problem in treatments 4 and 1. The use of this averaged comparison is supported by similarity of yields among non-modified treatments. This similarity resulted from the absence of severe water deficit stress during the growing season.

The relative yield response to tillage treatments can be seen graphically in figure 3. Two general observations from figure 3 were that PM treatments produced more seed cotton than non-modified treatments, and that yield increased with modification depth. In 1994, the annual PM treatments (5, 6, and 7) were the same as residual PM treatments with the same respective depths (8, 9, and 10) because all treatments had been installed the previous fall. In 1994, average seed cotton yields from same depth PM treatments were 500 kg/ha, 208 kg/ha, and 87 kg/ha more for the 76 cm, 50 cm, and 25 cm depths, respectively, than the 2754 kg/ha produced by non-modified treatments.

Similar results were observed in 1996. Annual PM treatments with depths of 76 cm, 50 cm, and 25 cm

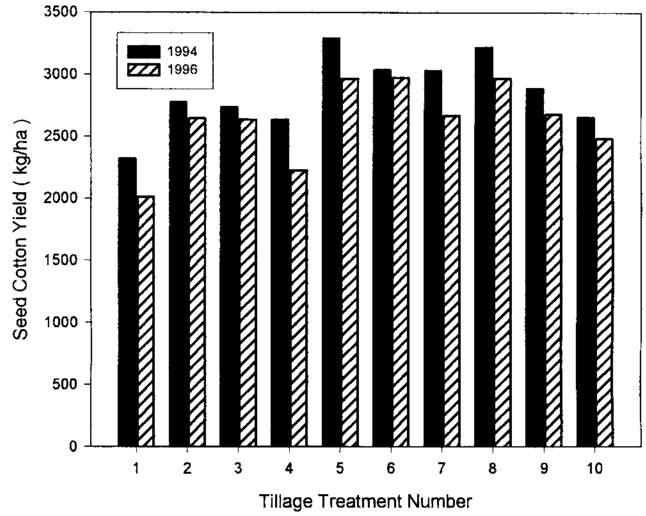

Figure 3–Seed cotton yield from the soil-profile modification study installed on Tunica clay in a wide-bed controlled-traffic production system.

produced 328 kg/ha, 335 kg/ha, and 31 kg/ha more seed cotton, respectively, than the 2638 kg/ha produced by non-modified treatments. The residual PM treatments in the same depth sequence produced 329 kg/ha, 41 kg/ha, and –154 kg/ha more seed cotton, respectively, than non-modified treatments. These residual plots had been in place since October 1993 without additional modification, but yield response from the 76-cm depth of modification was still as good as the 76-cm annual PM treatment. Based upon results of previous research, the differences between the non-modified treatment standard used in this report (average of disked and chiseled treatments) and the PM treatments would likely be much greater for a growing season in which water deficit stress was more severe.

Fiber quality data from table 6 shows that grade index was correlated with tillage but that staple length, micronaire, fiber strength, and length uniformity were not. Treatments 5 and 8 (76 cm depth) had the best average grade index of 98.5 and 99, respectively. All modified profile treatments had better grade index values than non-modified treatments. This was due to less trash in the harvested seedcotton. The modification tillage improved the control of honeyvine milkweed in the PM treatments relative to non-modified treatments; therefore, less trash

Table 6. Lint quality measurements for the 1994 harvest of profile modification tillage study treatments

Treat-ment	Description	Grade Index	Staple Length (mm)	Micro-nair	Fiber Strength (gm/tex)	Length Unifor-mity
1	Rehip - annual*	95.5	27.2	5.1	26.4	82.0
2	Disk - annual	95.7	27.4	5.0	26.3	82.4
3	Chisel - annual	94.5	27.2	4.9	26.4	82.3
4	Subsoil - annual	94.0	27.2	4.8	26.5	82.3
5	76 cm PM - annual	98.5	27.3	4.8	25.8	82.6
6	50 cm PM - annual	98.0	27.5	4.9	25.7	82.5
7	25 cm PM - annual	98.5	27.3	5.0	26.0	82.1
8	76 cm PM - residual†	99.0	27.3	4.9	25.7	82.2
9	50 cm PM - residual	98.0	27.4	4.9	26.0	82.7
10	25 cm PM - residual	96.3	27.2	4.8	26.1	81.9
	$LSD_{0.05}$	2.8	0.48	0.2	0.5	0.5

* Tillage performed annually in the fall after harvest.
† Profile modification tillage performed fall of 1993 only.

was harvested with the seedcotton. The remaining fiber quality measurements were in the normal range except for some micronaire values. Staple length ranged from 27.2 mm to 27.4 mm. Micronaire was within the base range except for T1 and T2 that fell in the discount range with values of 5.0 and 5.1. Fiber strength values ranged from 25.7 to 26.5 g/tex and that is considered to be in the intermediate range for fiber strength. Degree of uniformity was also intermediate with values ranging 81.9 to 82.7.

In general, a positive crop response was observed for profile modification tillage. However, the practice, as performed in this study, would not be practical for crops on large areas. The field capacity of the profile modification machine operating in the wide-bed production system (0.071 km/h $\times$ 2m bed) was 0.0142 ha/h and that translates to 70.4 h of continuous running per hectare. The crop response to profile modification was not sufficient to justify this level of investment in time and resources.

Profile modification might be a viable practice for high value crops grown on small areas. Where needed, this practice could provide a means for uniformly incorporating soil amendments such as organic matter or plant nutrients throughout the profile while also removing mechanical restrictions to root proliferation and water movement. The practice would not have to be repeated each year if machinery traffic was restricted from the modification zone; therefore, the cost of profile modification could be distributed over several years.

CONCLUSIONS

Conclusions reached as a result of this study were:

1. Soil profile modification generally increased plant height, vegetative dry mass, and seed cotton yield compared to conventional tillage practices used in this study.
2. The residual effect of soil profile modification at the 76-cm depth was as effective in increasing seed cotton yield as annual modification tillage after three years.
3. The yield response of cotton to soil profile modification was not sufficient to justify the time expenditure of 70.4 h/ha required to perform the practice.

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REFERENCES

Eck, H. V., and H. M. Taylor. 1969. Profile modification of a slowly permeable soil. *Soil Sci. Soc. Am.* 33(5): 779-783.

Heilman, M. D., and C. L. Gonzalez. 1973. Effect of narrow trenching in Harlingen clay soil on plant growth, rooting depth, and salinity. *Agron. J.* 65(5): 816-819.

Mech, S. J., G. M. Horner, L. M. Cox, and E. E. Cary. 1967. Soil Profile Modification by backhoe mixing and deep plowing. *Transactions of the ASAE* 10(6): 775-779.

Smith, L. A. 1993. Implement for deep soil-profile modification. ASAE Paper No. 93-1112. St. Joseph, Mich.: ASAE.

Smith, L. A. 1995. Cotton response to deep tillage with controlled traffic on clay. *Transactions of the ASAE* 38(1): 45-60.

Wesley, R. A., and L. A. Smith. 1991. Response of soybean to deep tillage with controlled traffic on clay soil. *Transactions of the ASAE* 34(1): 113-118.

Williford, J. R. 1980. A controlled-traffic system for cotton production. *Transactions of the ASAE* 23(1): 65-70.